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Mathematical Modeling of Population Dynamics of the *Aedes Aegypti* (Diptera: Culicidae) Mosquito with Some Climatic Variables in Villa Clara, Cuba

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Opinion

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Abbreviations: TX: Maximum Temperatures; TM: Average Temperatures; TN: Minimum Temperatures; HRX: Maximum Relative Humidity; HRM: Average Relative Humidity; HRN: Minimum Relative Humidity; AP: Air Pressure; VMV: Average Wind Speed.

Opinion

Millions of people suffer from infections transmitted by arthropod vectors; among them, culicids are undoubtedly the most important in terms of hygiene and health, because they are one of the priority health problems in almost all tropical and subtropical regions. The objective of the study was to establish a forecast model among some meteorological variables for the focus of the *Aedes aegypti* mosquito species, during the period from 2007 to 2017 in the province of Villa Clara, Cuba. The research covered the 13 municipalities of the province, as well as the number of outbreaks reported by them in the different months of the period analyzed. Regressive Objective Modeling was used for the development of the predictive model. Likewise, the response variable was defined as: the focus for *Ae. aegypti* and as explanatory variables, the meteorological variables: Maximum Temperatures (TX), Average Temperatures (TM), Minimum Temperatures (TN), Maximum Relative Humidity (HRX), Average Relative Humidity (HRM), Minimum Relative Humidity (HRN), Provincial Precipitation (Prec.), Air Pressure (AP), Average Wind Speed (VMV) and Cloudiness (Cloud). The data for both variables came from the same time period (2007- 2017), and were provided by the Villa Clara Provincial Meteorological Center, which covers the four meteorological stations in the province (Santa Clara, Manicaragua, Caibarién and Sagua La Grande). Data processing was done by Pearson and t student correlations, as a test of statistical significance with the SPSS statistical package ver.13. A perfect model was obtained for each of the studied municipalities, with the combination of delays 1, 2, and 6, and the influence that the meteorological variables have in the modeling of the population dynamics of the *Ae. a* mosquito was demonstrated.

Emerging and re-emerging infectious diseases are one of the health problems that have raised the most interest in the different countries of the world in recent years, since many of such diseases are considered national disasters due to the high morbidity they generate, the large number of lives they take, and the cost they represent for the country from the economic point of view. They are more than just health problems, they become economic issues since they affect tourism, industry, exports, and the health sector needs to provide resources to control the disease. Millions of people suffer from infections transmitted by arthropod vectors, including culicids, which are undoubtedly the most important in terms of hygiene and health because they are one of the priority health problems in almost all tropical and subtropical regions and are responsible for the maintenance and transmission of the pathogens that cause dengue fever, yellow fever, West Nile fever, Chikungunya, Zika, Malaria, and Lymphatic Filariosis, among other deadly and debilitating infections.

In the Americas, yellow fever remains a persistent threat. Between 1985 and 2012 there were 4 066 confirmed cases of yellow fever, of which 2 351 (58%) died. Between 1980 and

2012, 150 outbreaks of yellow fever have been reported in 26 African countries, with more than 200 000 cases occurring globally. From December to February 2017, an outbreak of yellow fever affected Brazil, with 1 345 suspected cases, 295 confirmed cases, and 215 deaths. Dengue fever has spread in recent decades and continues to be the main arbovirus disease. Additionally, Chikungunya and Zika have emerged in recent years. Malaria remains the world's leading parasitic health problem, an estimated 429 000 deaths were recorded in 2015. About 90% of malaria-related deaths globally occur in Africa, with 70% occurring in children under five years of age. This problem is now being aggravated by global warming and the intensification of extreme weather events, which have brought about changes in the behaviour of diseases and their transmitters, with the establishment of vector species in previously unrecorded locations. Weather conditions are considered to be one of the most important factors related to the spread of dengue fever outbreaks. Increases in temperature, humidity and rainfall volume are among the most influential climate variables reported.

In Cuba, the incidence of these entities, both parasitic and viral, is undoubtedly a health problem, with a tendency to increase the number of cases, as well as the populations of vector organisms. The emergence and re-emergence of arbovirus infections has increased in the last decade. The changing epidemiology and the factors responsible for the dramatic resurgence of such diseases are complex. A large percentage of human diseases are zoonotic. In addition, global and focal demographic, social and environmental changes have led to the spread of infection to humans. Seasonality and year-to-year variation in disease incidence are more marked for arboviral diseases, as vector reservoirs are susceptible to seasonal changes. Climatic conditions and the transmission dynamics of these diseases are interlinked, and since nowadays the world knows more about meteorological parameters, the impact of climate change can and should be mitigated. Over the past 50 years or more, models of emerging arbovirus diseases have changed significantly. Climate is the primary factor in determining the temporal and geographic distribution of arthropods, the characteristics of their life cycles, the consequent dispersal patterns of associated arboviruses, the evolution of arboviruses, and the efficiency with which they are transmitted from arthropods to vertebrate hosts. Although it is well known that meteorological variables are determinant in the transmission of arboviruses diseases, in our province there are few studies on the effect of some of these variables on larval densities of culicids with entomoepidemiological importance.

Mathematical Modeling

Regressive Objective Modeling (ROR) was used to develop the predictive model. The response variable was defined as: the focus for *Ae. aegypti* and the explanatory variables were: maximum temperatures (TX), average temperatures (TM), minimum temperatures (TN), maximum relative humidity (HRX), average relative humidity (HRM), minimum relative humidity (HRN), provincial precipitation (Prec.), Air Pressure (AP), Average Wind Speed (VMV) and Cloudiness (Cloud). The data for both variables response and explanatory correspond to the same time period (2007-2017). The data of the meteorological variables were requested to the Villa Clara Provincial Meteorological Center, from the four meteorological stations of the province, located in the municipalities of Santa Clara, Manicaragua, Caibarién, and Sagua La Grande. The data obtained were processed by means of Pearson and t student correlations, as a test of statistical significance in the SPSS statistical package ver. 13. For the forecasting of the foci, the modeling was carried out by means of the Regressive Objective Regression ROR methodology, for which dichotomous variables DS, DI and NoC were created in a first step, where: NoC: Number of cases in the base, If NoC is odd, then DS = 1 and DI = 0; if NoC is even, then DS = 0 and DI = 1; when DI=1, DS=0 and vice versa.

Later, the module corresponding to the SPSS statistical package version 19.0 Regression analysis (IBM Company, 2010) was carried out, specifically the ENTER method where the predicted variable and the ERROR are obtained. Then the autocorrelations of the variable ERROR were obtained, with attention to the maximum values of the significant partial autocorrelations PACF. The new variables were then calculated taking into account the significant Lag of the PACF. Finally, these variables were included in the new regression in a process of successive approximations until obtaining a white noise in the errors of the regression. In the case of atmospheric pressure, the delays of one year were used, as other authors did for the climate indexes, although it is unlikely that results will be obtained 11 years in advance, since only data from 11 years in the base is available. However, in the monthly data, the results for the meteorological variable atmospheric pressure were used.

We chose the ROR model of the province, since in the course of the research it was concluded that with the combination of delays 1, 2 and 6 a perfect model was obtained for each of the municipalities. It can be seen how 100% of the variance is explained, with a standard error that is practically imperceptible; the Durbin Watson statistic indicates that there is no information on the residuals, since a perfect model was obtained with the data analyzed. In relation to the modeling for the province, we can appreciate how the predicted value has excellent coincidence with the real value, from the year 2013 to 2017, where the prediction for 2018 was to remain similar to the previous year. The

analysis of model variance indicates that Fisher's F cannot be determined because the residuals are zero.

A forecast was made with statistical variables only, and then, climatic variables were also included, those that had the greatest correlation with the errors of pure statistical models, taking into account the proximity of the weather station. The correlations between the real value and the value predicted by both models were calculated, observing that 9 models with climatic variables exceed the pure statistical ones and 4 models remain the same, since the climatic variables were not significant. The climatic variables that entered as significant in the models, for example in Santa Clara, the Atmospheric Pressure and the Average Relative Humidity in Yabu entered as significant. The Skill was defined as: SKILL = (1- (Pure Model / Model with climatic variables)) *100. Santa Clara is where it was best modelled with climatic variables, with 52.14 % (Table 1).

Municipalities	Pure Statistical Model	Model with climatic variables	SKILL (%)	Climatic variables
Corralillo	0.287	0.515**	44	Average Temperature Sagua
Quemado	0.486*	0.486**	-	-
Sagua	0.505**	0.505**	-	-
Encrucijada	0.726**	0.726**	-	-
Camajuaní	0.475**	0.626**	24.12	Average Humidity Sagua
Caibarién	0.741**	0.882**	15.99	Rainfall
				Sagua
Remedios	0.538**	0.538**	-	-
Placetas	0.657**	0.658**	0.15	Atmospheric Pressure Yabú
Santa Clara	0.246	0.514**	52.14	Atmospheric Pressure
				Average Relative Humidity
				Yabú
Cifuentes	0.617**	0.681**	9.4	Cloudiness
				Yabú
Santo Domingo	0.370*	0.593**	37.61	Minimum Relative Humidity
				Sto. Domingo
Ranchuelo	0.382**	0.482**	20.75	Average Wind Speed Yabú
Manicaragua	0.686**	0.751**	8.66	Atmospheric Pressure Average Relative Humidity
				Yabú

Table 1: Correlations between predicted and actual value by municipality.

We observe that the model depends on the data from the foci a year and a month ago (Lag13Focos), two years and a month ago (Lag25Focos) and 6 years and a month ago (Lag73Focos), although they are not significant variables, they provide variance to the model, followed by the average relative humidity and the atmospheric pressure variables in Yabú. The trend is negative, although not significant. In the case of the municipality of Santa Clara, the model obtained depended on the average relative humidity and atmospheric pressure variables in the Yabú station; thus, as the average relative humidity increased in 1%, the number of foci this increased in 35.5; while, as the atmospheric pressure increased in 1 Hectopascal, the foci decreased in 2.2. The influence of meteorological variables on the modeling of the population dynamics of the *Ae. a* mosquito with entomoepidemiological importance was demonstrated.